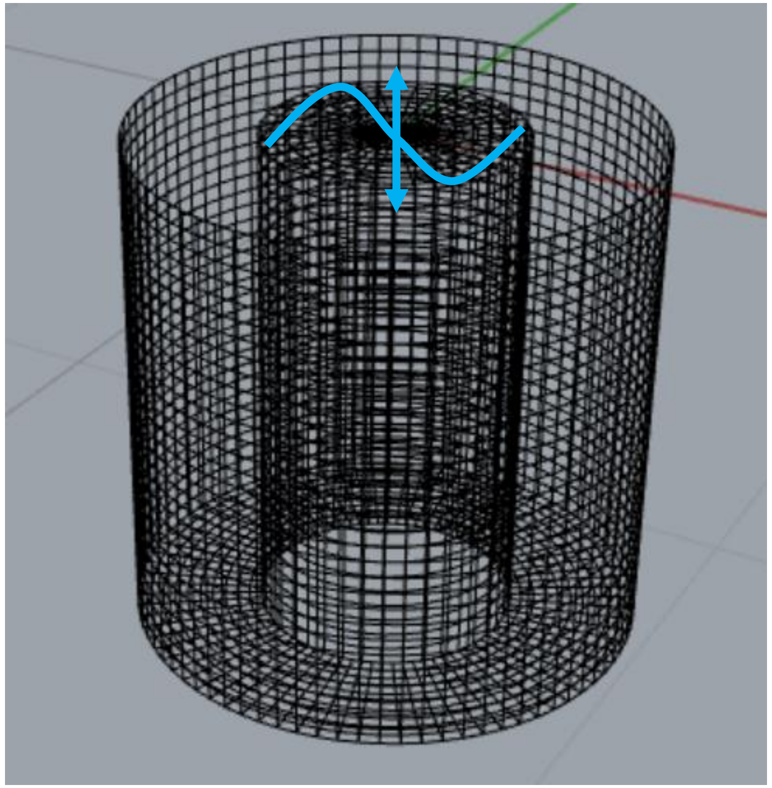
Modeling OWC Devices

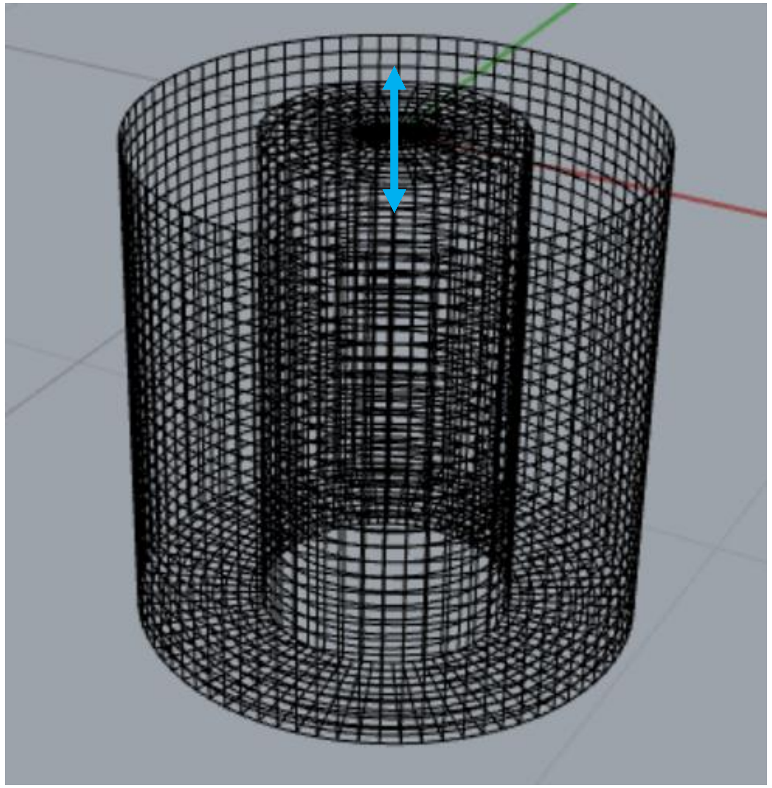
WEC-Sim Training- Advanced Features

Meshing

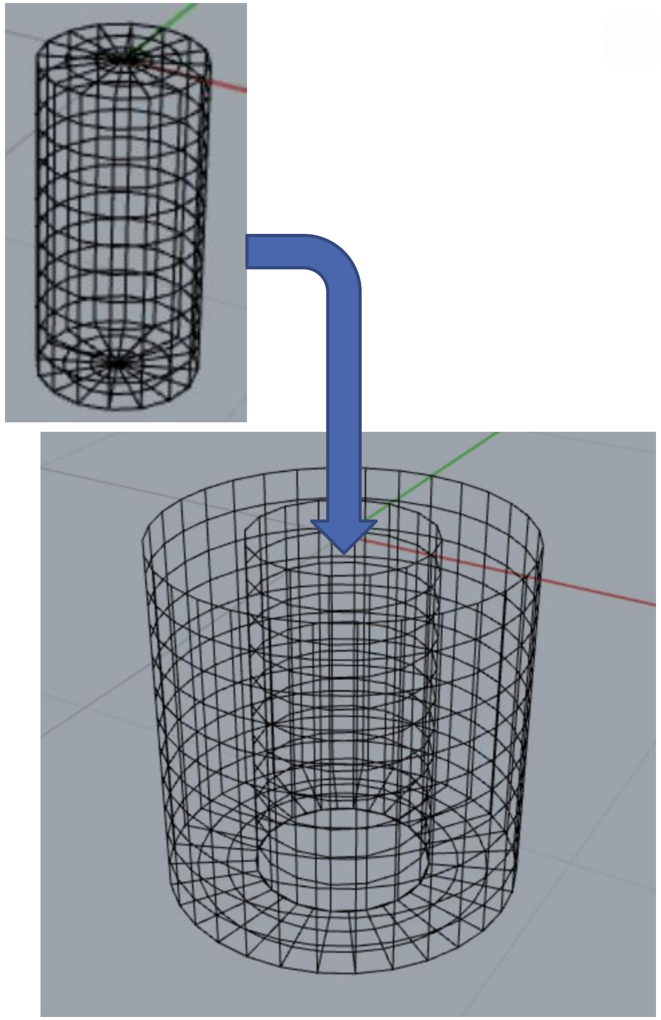
WEC-Sim team uses 3 primary ways to model OWC in BEM codes



Generalized Body Modes (GBM)



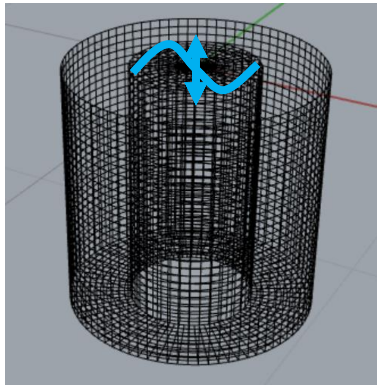
Free Surface Pressure (FSP)



Two Rigid Bodies

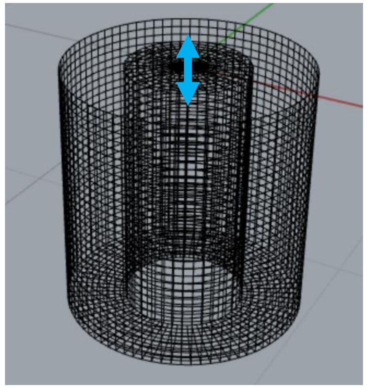
Meshing

WEC-Sim team uses 3 primary ways to model OWC in BEM codes



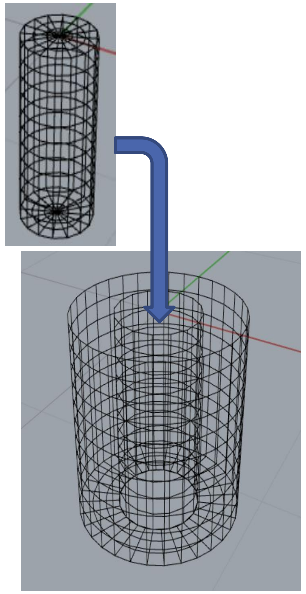
Generalized Body Modes (GBM)

+/- A WAMIT/Capytaine feature that *can* be implemented directly, but you probably need to modify *defmod.f*
+ Can describe many surface modes (i.e., sloshing/pitching)
- Large undamped responses
- Custom WEC-Sim for control
- Careful with infinite-frequency added mass!



Free Surface Pressure (FSP)

+ A WAMIT feature can be implemented directly on low-order GDFs
+ Well-described boundary conditions
- A "zero mass" surface → large undamped responses
- Heave-only surface
- Custom WEC-Sim for control

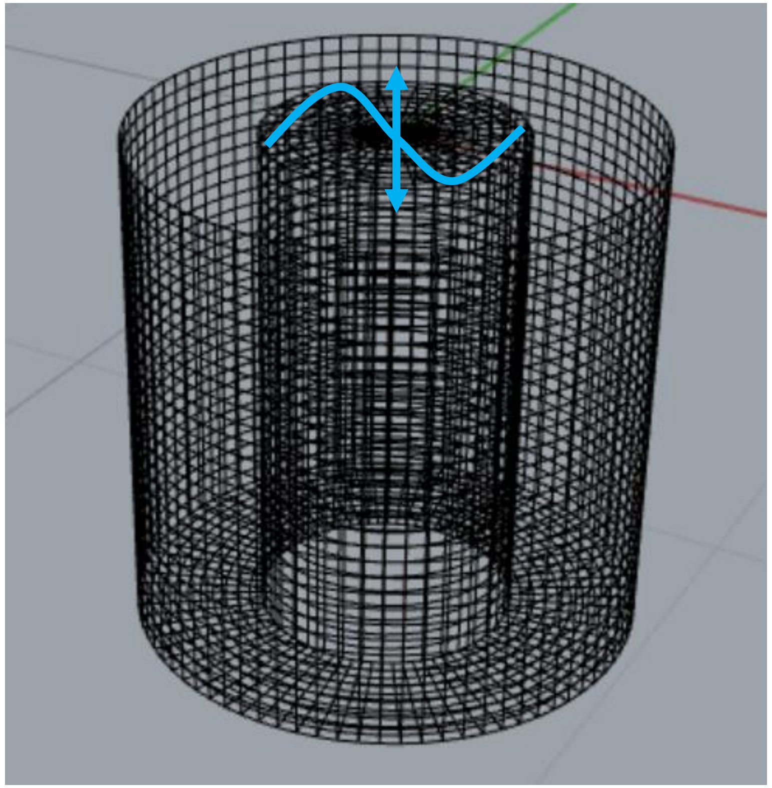


Two Rigid Bodies

+ The most intuitive
+ Doable with most BEM codes
+ Standard WEC-Sim blocks→ can model PTOs, controls, etc. w/o modification.
- Not so great for floating OWC
- Can be painful to tune
- Heave-only surface(?)

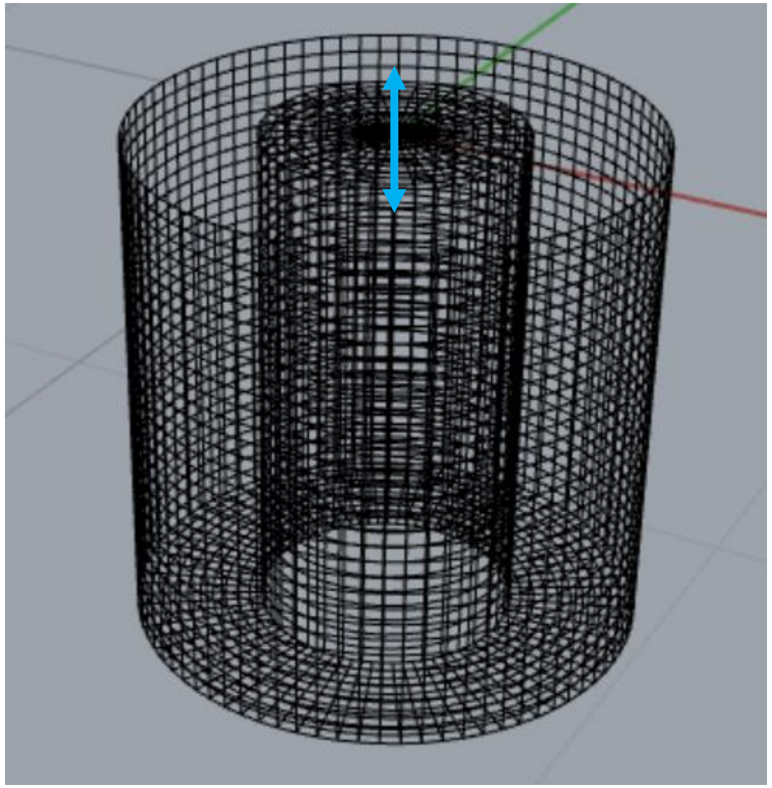
Meshing

WEC-Sim team uses 3 primary ways to model OWC in BEM codes



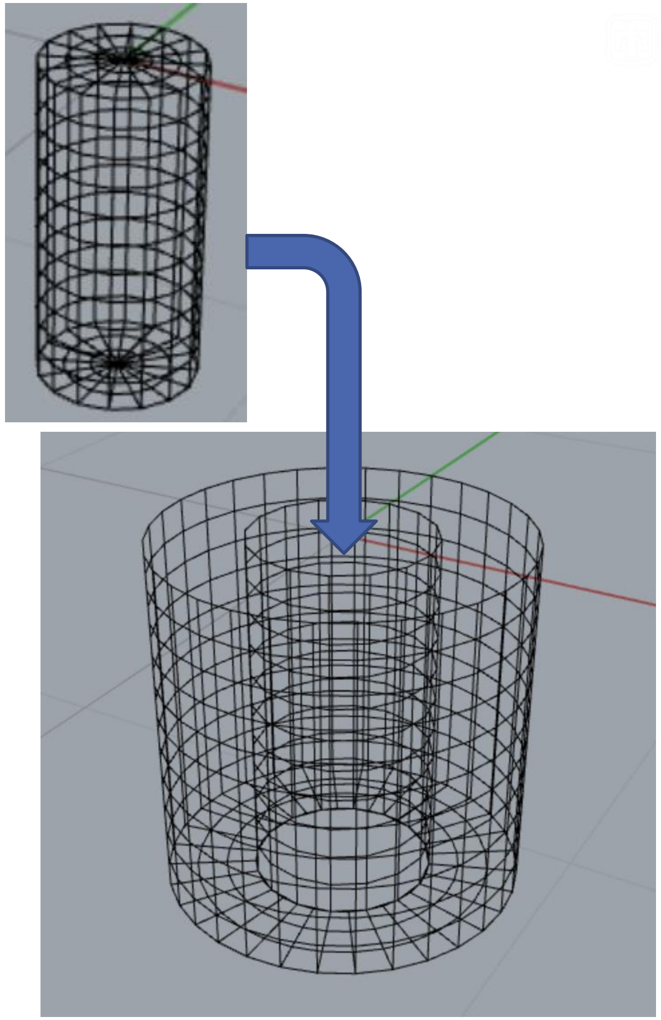
Generalized Body Modes (GBM):

*Recommended in general



Free Surface Pressure (FSP)

* Recommended in WAMIT alongside GBM



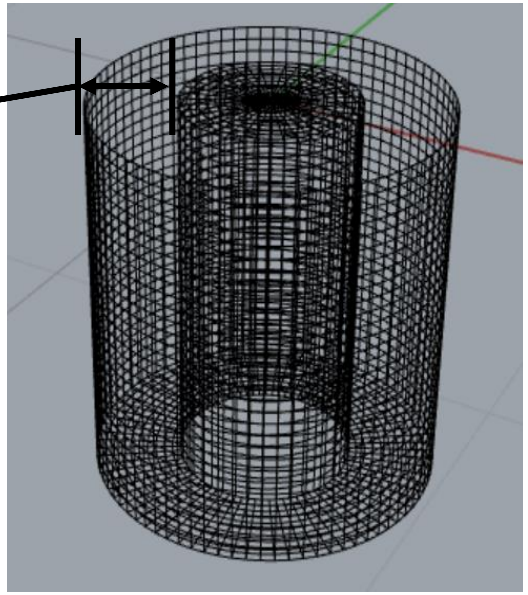
Two Rigid Bodies

* Recommended for fixed OWC, if necessary

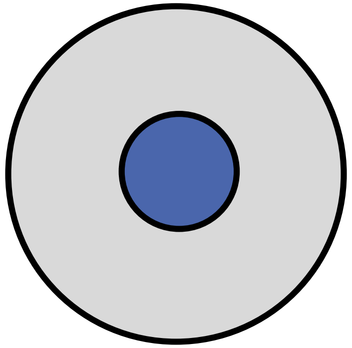
Meshing

Some common difficulties

This can be a thin surface (consider dipoles, a 2D approximation)



Some geometries require multiple embedded loops of panels i.e. top view:



Very large panel numbers

Undamped free-surface motion in BEM potential flow solution

Internal reflections surge/pitch when wavelength ~ moonpool length

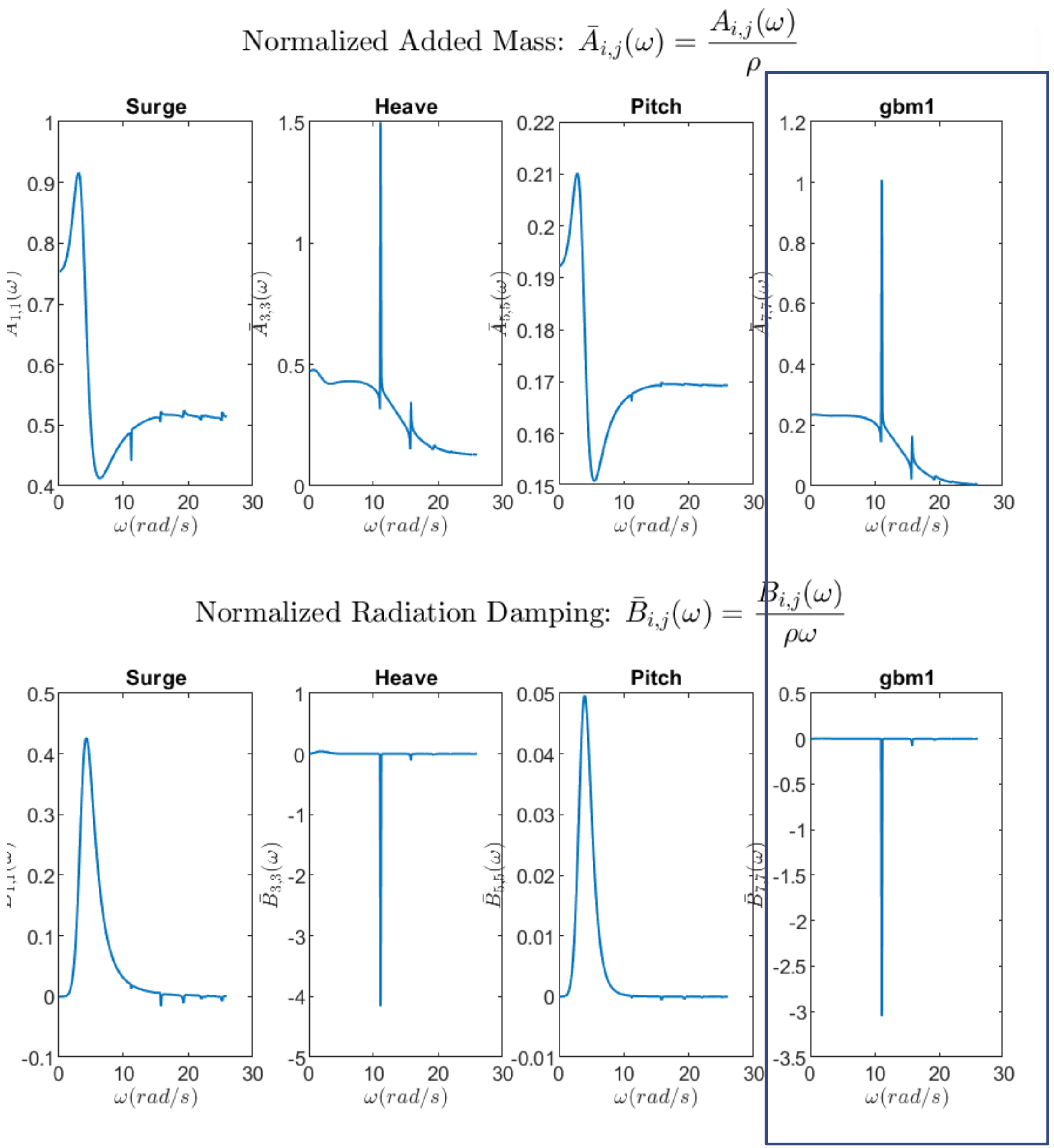
Hydrodynamics

Good hydrodynamics should be:

- Smooth
- Added mass → constant as ω → ∞
- Radiation damping → 0 as ω → ∞
- Radiation damping (on diagonals) > 0
- **For OWC: infinite frequency added mass ~ highest-frequency added mass**
- Well-resolved over frequency range of interest
- Your IRFs should smoothly decay to zero over time!

OWC BEM results will frequently have non-physical peaks that will drive the IRF results.

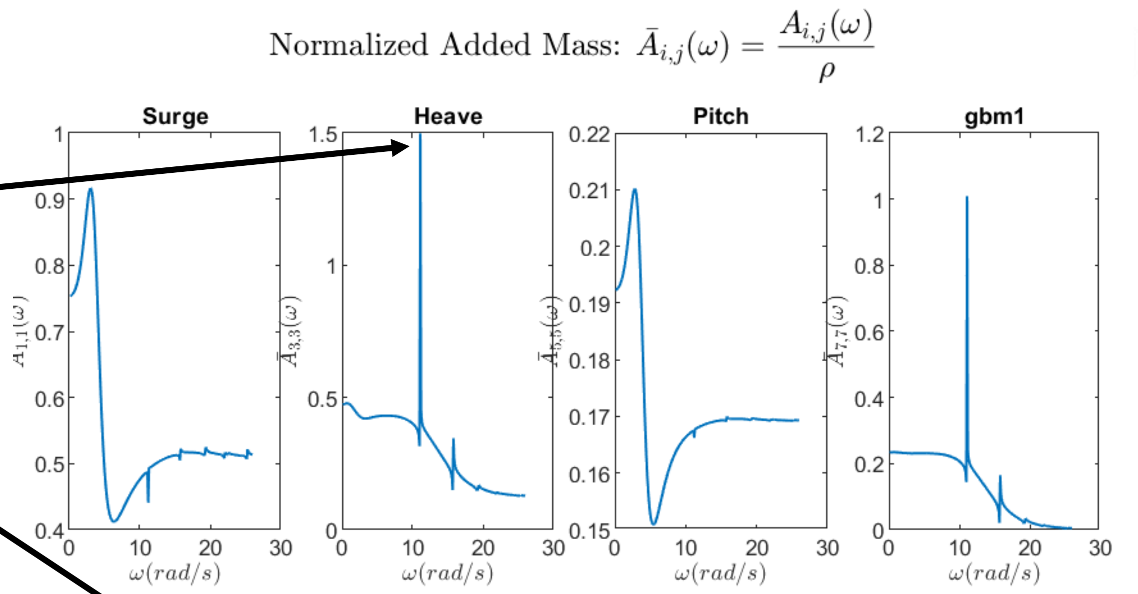
"GBM1" is the relative heave of the internal free surface

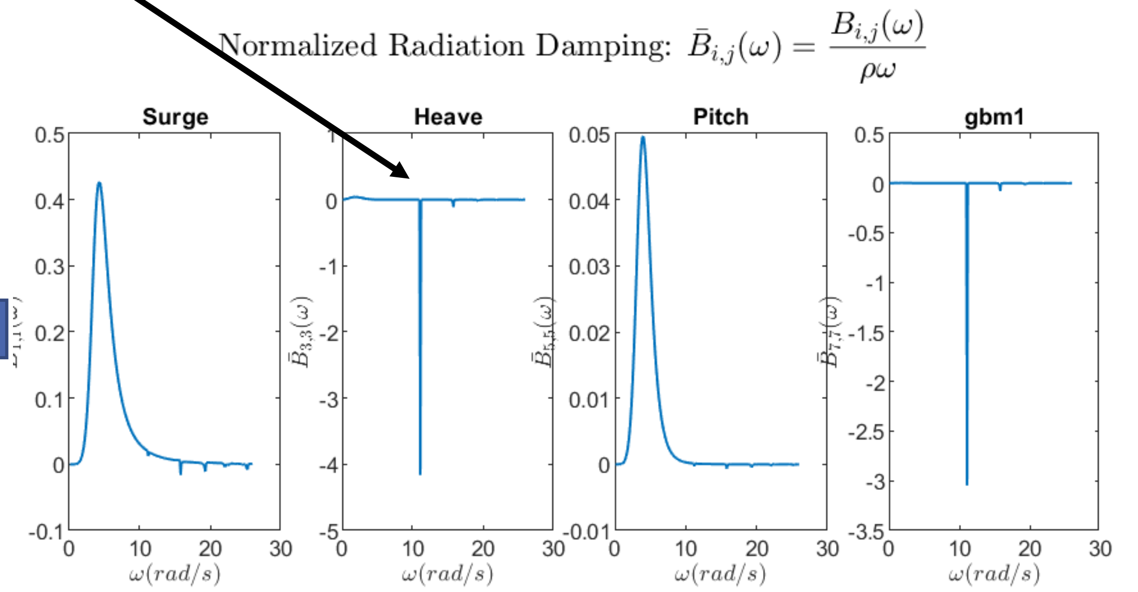


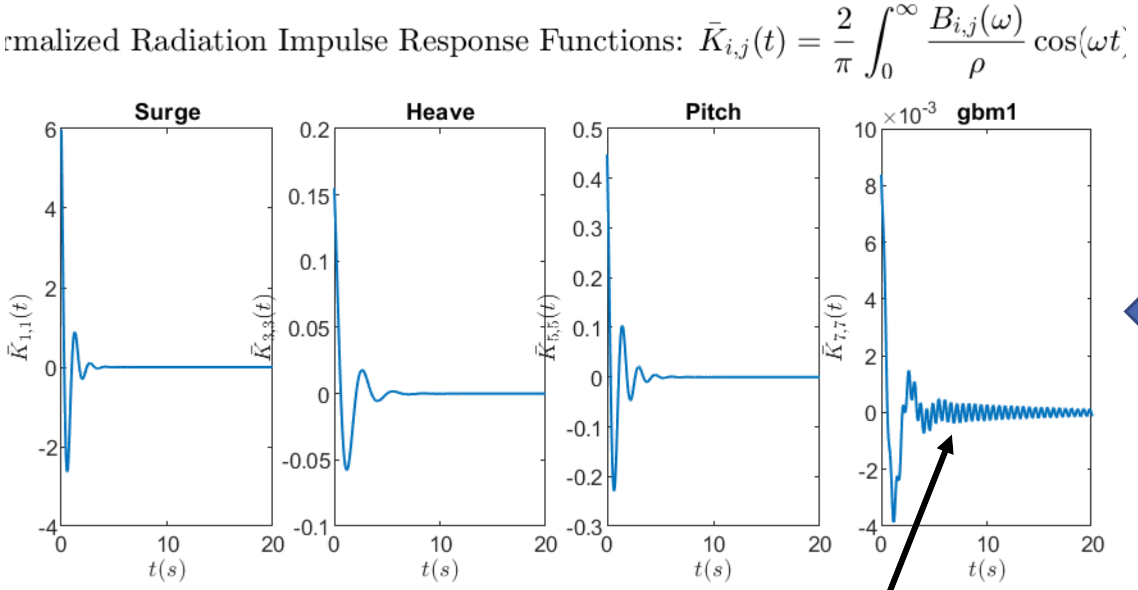
Hydrodynamics

These peaks correspond to a wave length of 0.5 m, the diameter of the internal moonpool.

More embedded loops of panels→ more similar resonances. In reality, viscosity and vortices will significantly attenuate this resonance.







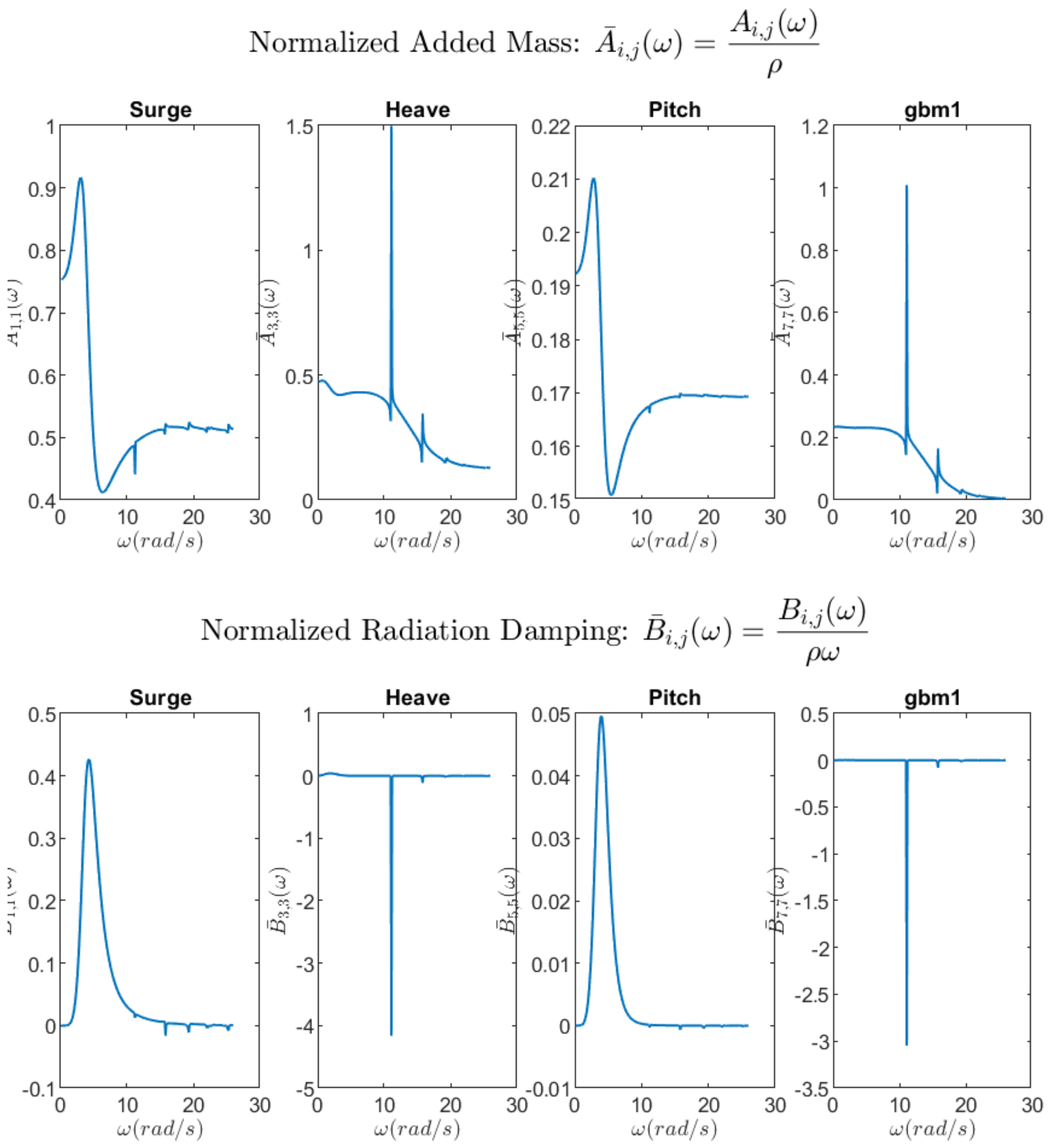
High frequency noise

Hydrodynamics

"Irregular frequency removal" should be attempted but will likely NOT work with resonances associated with the free surface of the physical moonpool: removing these peaks is recommended in post-processing before trying in WEC-Sim

Try the cleanup function in ``WEC-Sim/source/functions/BEMIO/badBemioFix_fcn.m``

Recommended reading: Kelly et. al, "A post-processing technique for addressing 'irregular frequencies' and other issues in the results from BEM solvers". *Proc. of EWTEC* 2021.

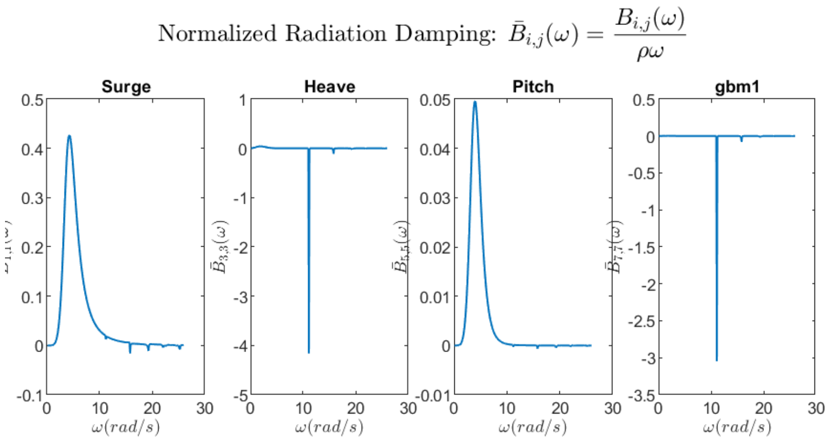


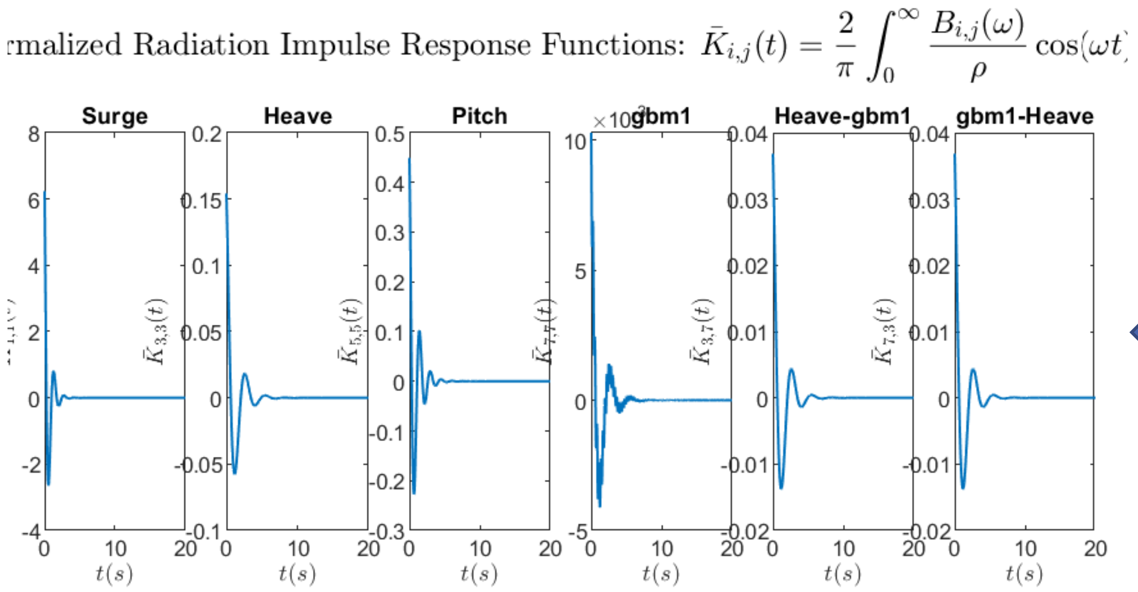
Hydrodynamics Clean up

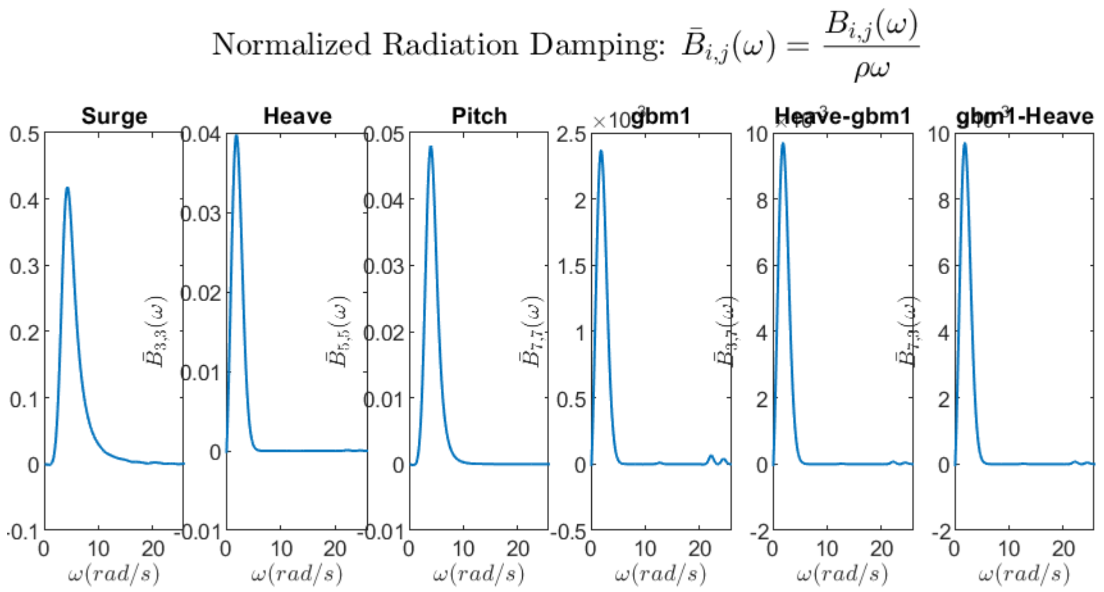
For added mass, radiation damping, excitation real and imaginary components:

- Remove spikes (at single frequencies)
- Apply back-to-back low-pass filtering
- → Results can better represent real physics

This BEM post-processor will be released on the dev branch soon (PR #1076)







Hydrodynamics

These resonances are non-physical and in reality will be dissipated by viscosity before the motions become large.

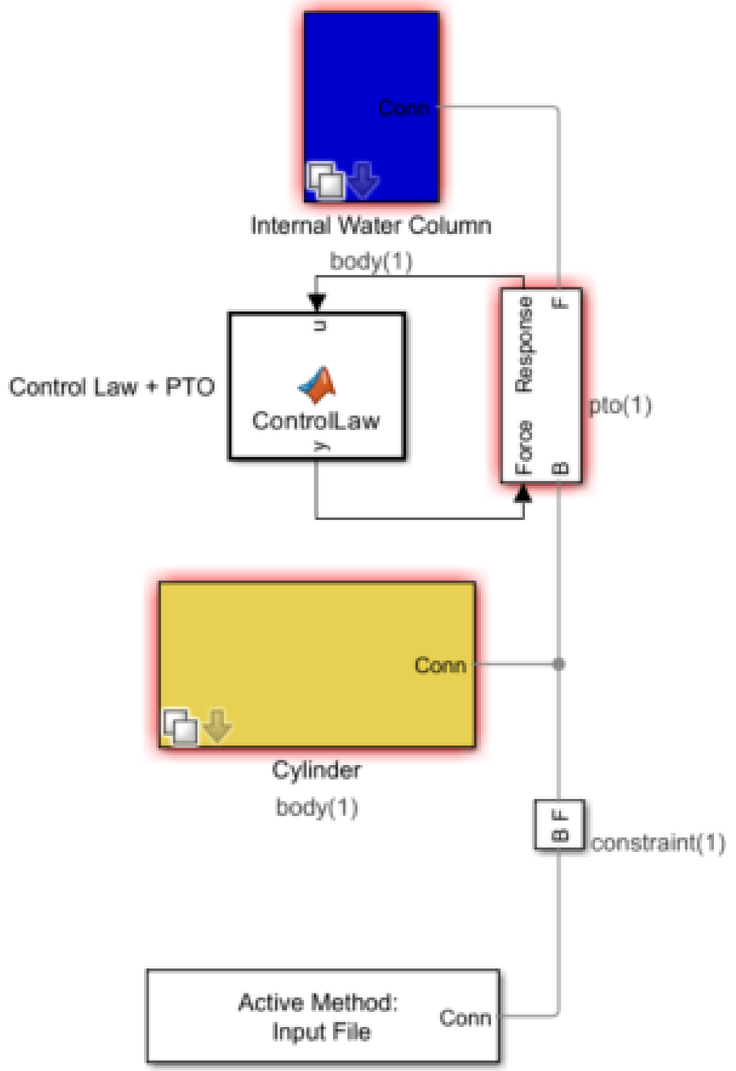
The lesson:

- In absence of tank data or a reference model, OWC modeling w/ potential flow has a high uncertainty
- Add significant damping to tune models
- Add ***frequency-dependent*** damping, which may be necessary to tune models

WEC-Sim modeling

The two-body BEM approach can be readily modeled with unmodified WEC-Sim blocks

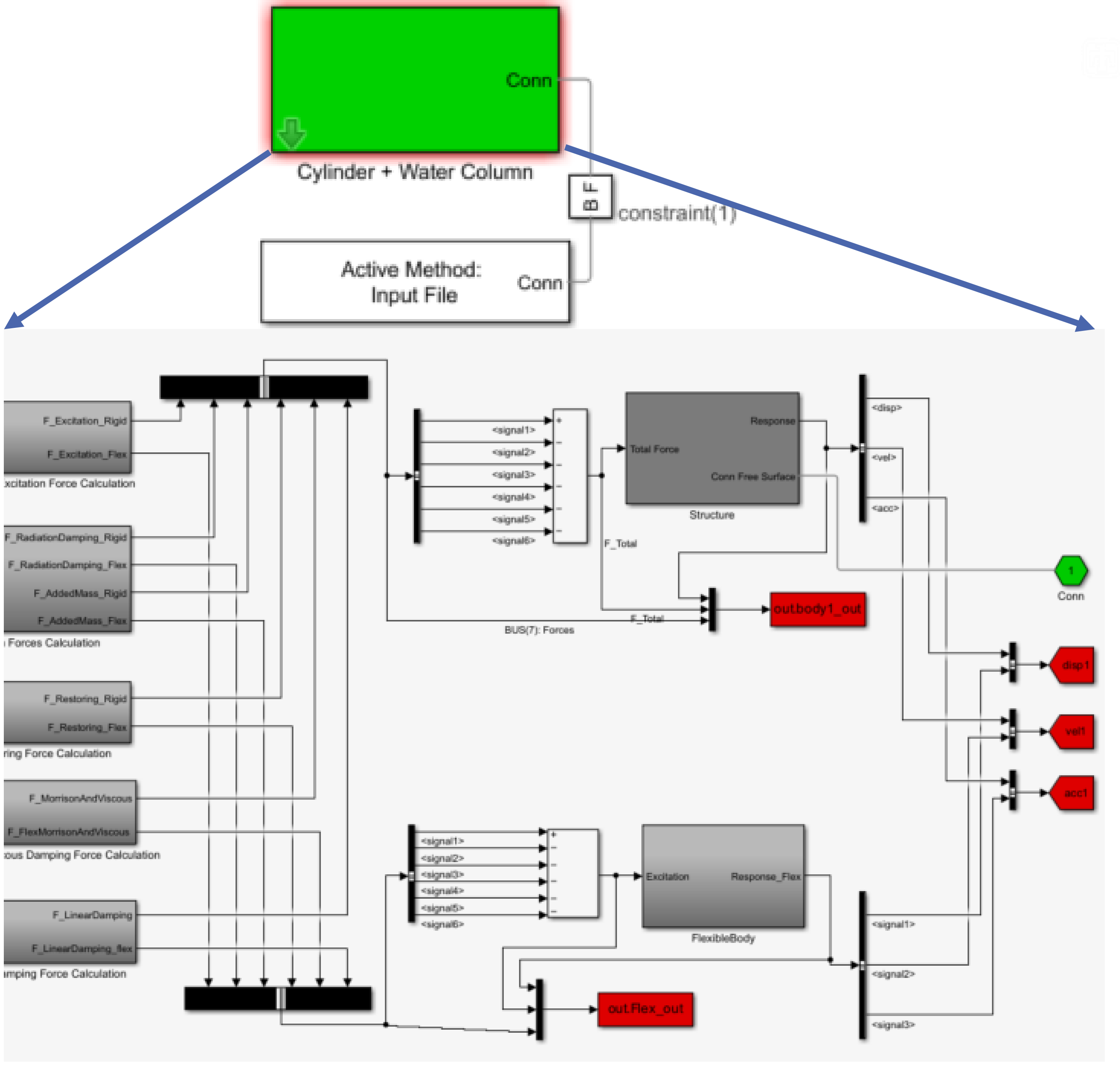
Orifice model, pistons, turbine models, etc. can be captured with a custom MATLAB function or sub-system in the force-actuated Translational PTO block



WEC-Sim modeling

Both the GBM and FSP BEM approaches will use a single flexible body model, with the “flexible mode” of the body being (at a minimum) the internal free-surface motion.

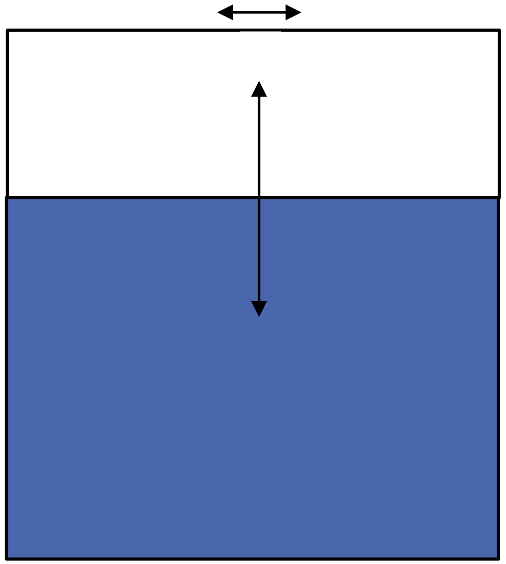
But as-is, this doesn’t account for any external coupling forces between free-surface and cylinder motion.

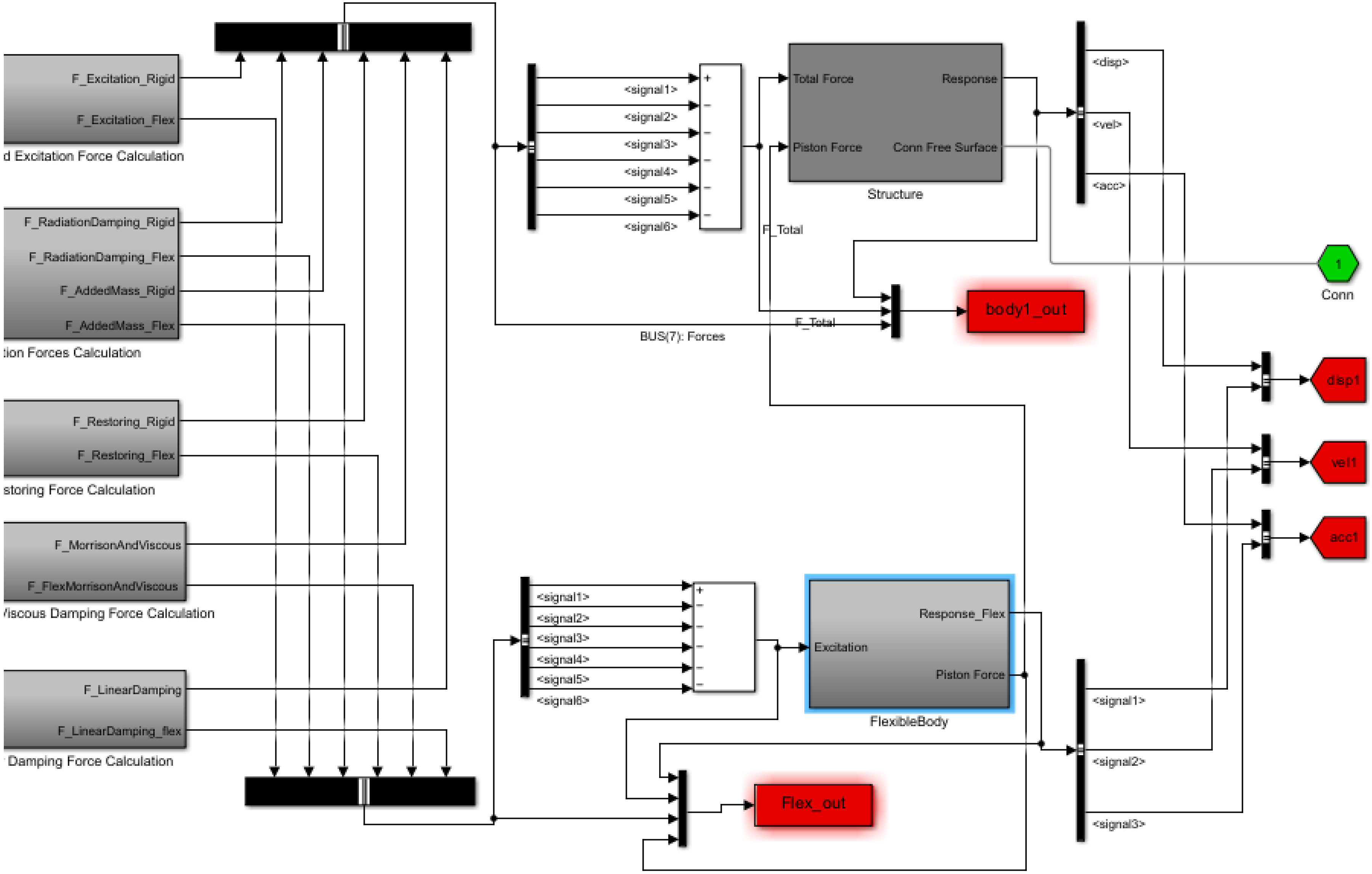


WEC-Sim modeling- Breaking the Library

Break the library to add PTO and other coupling forces between the heaving free surface and the cylinder.

Orifice Area

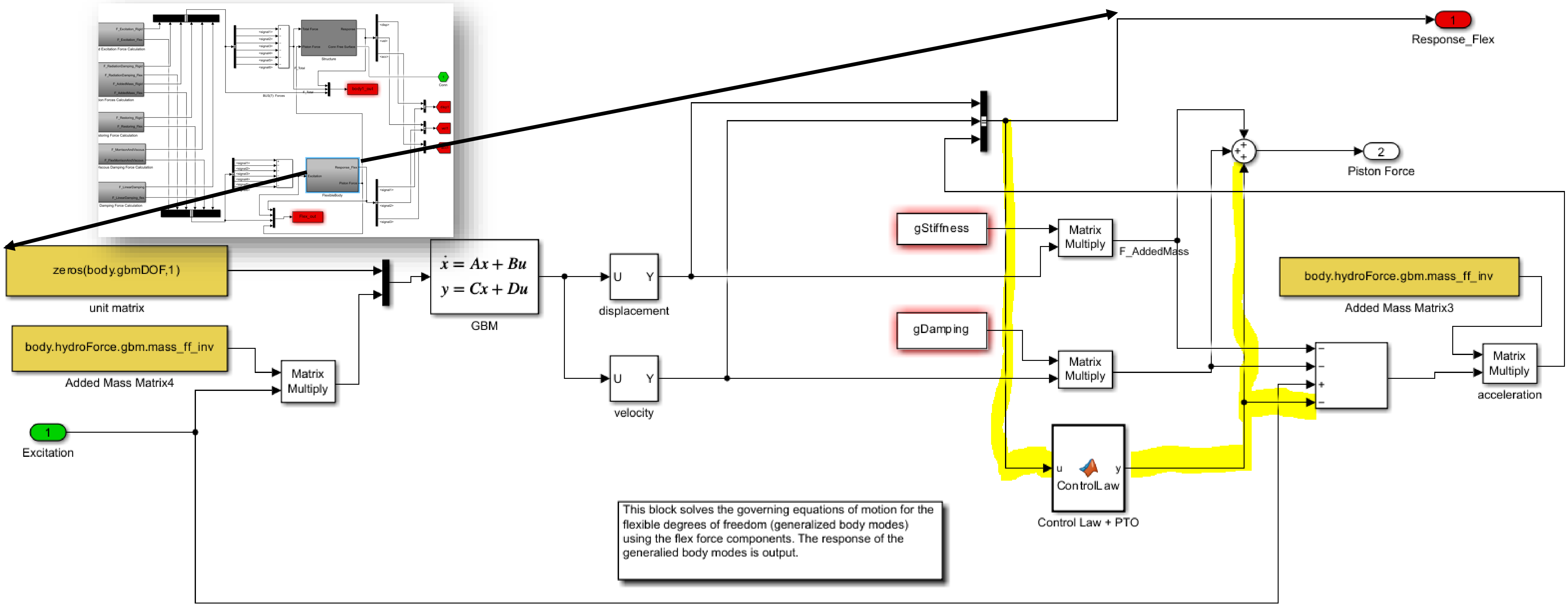




WEC-Sim modeling- Breaking the Library

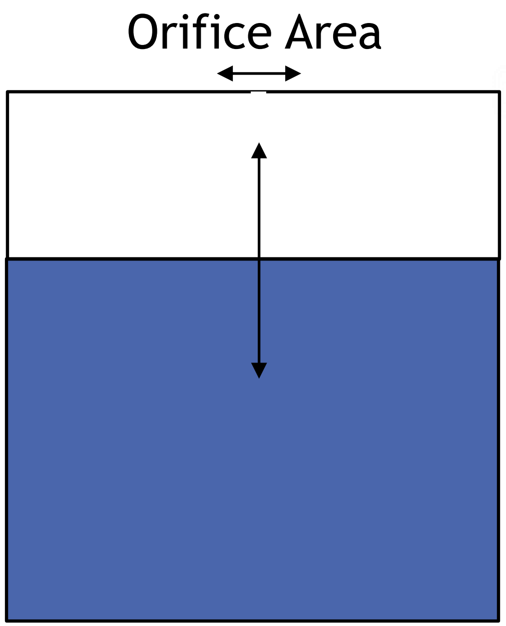
Both the GBM and FSP BEM approaches will use a single flexible body model, with the "flexible mode" of the body being the internal free-surface motion.

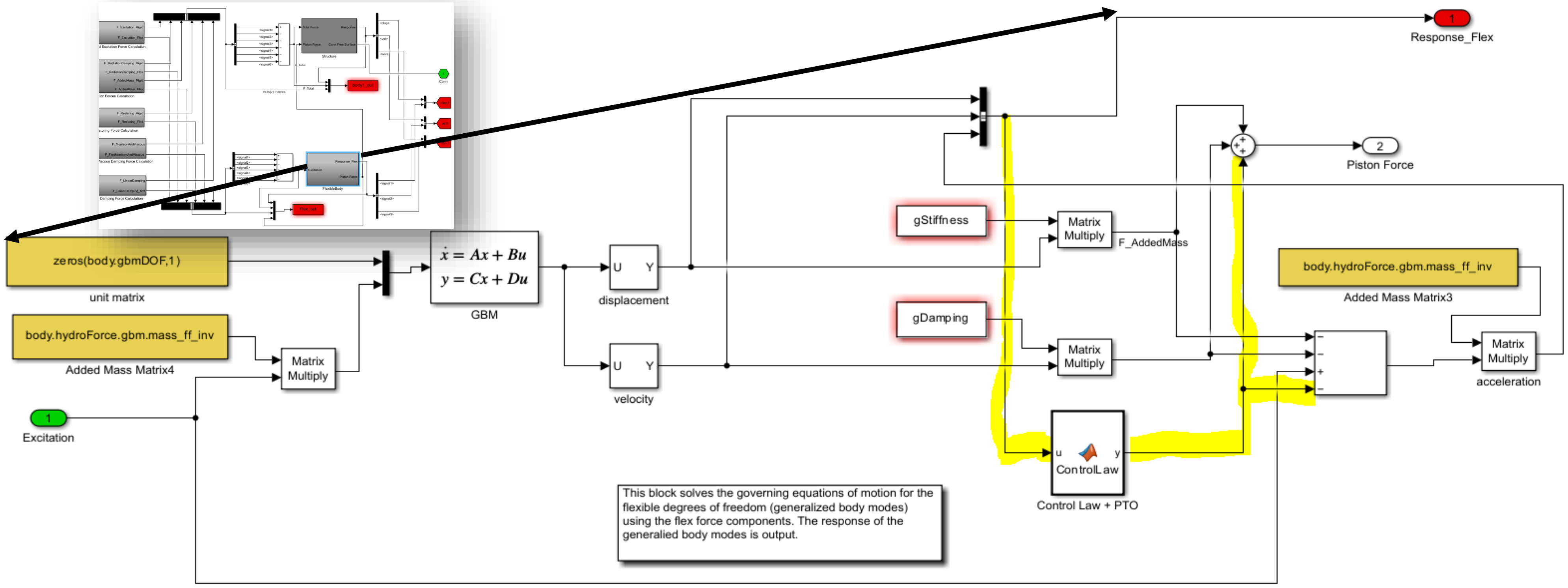
Break the library to add PTO and other coupling forces between the free surface and the cylinder.



WEC-Sim modeling- Example

Consider a fixed orifice area, define relationships between free surface velocity and force between the internal free surface in the "Control Law + PTO" block

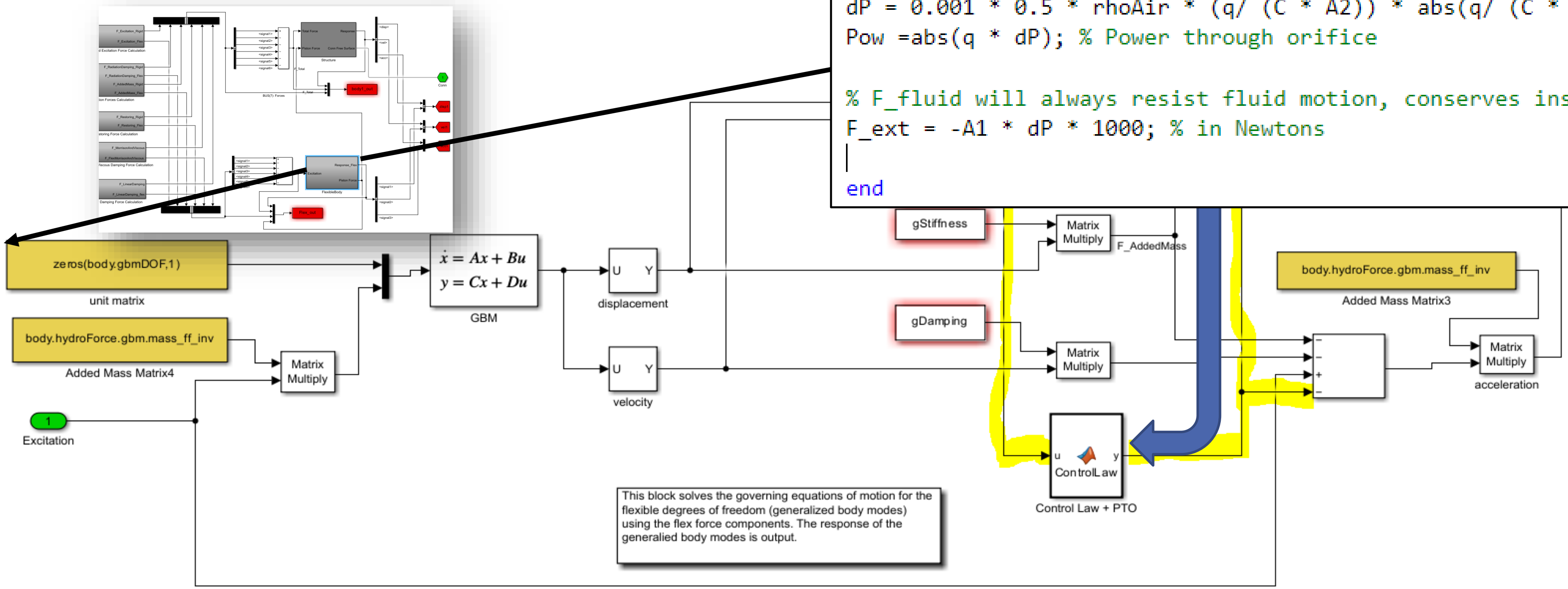




WEC-Sim modeling- Example

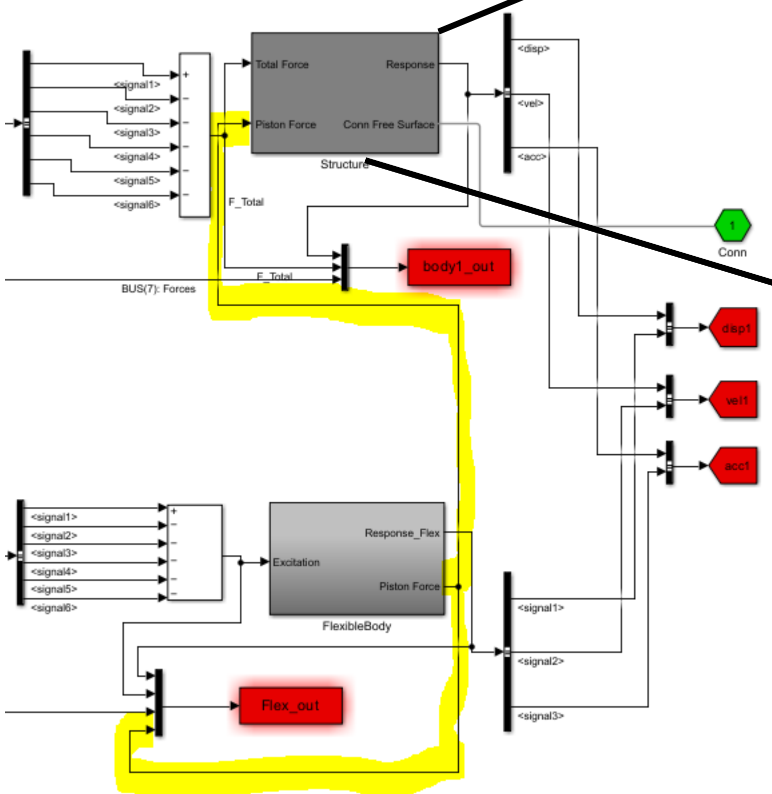
Consider a fixed orifice area, define relationships between free surface velocity and force between the internal free surface in the “Control Law + PTO” block

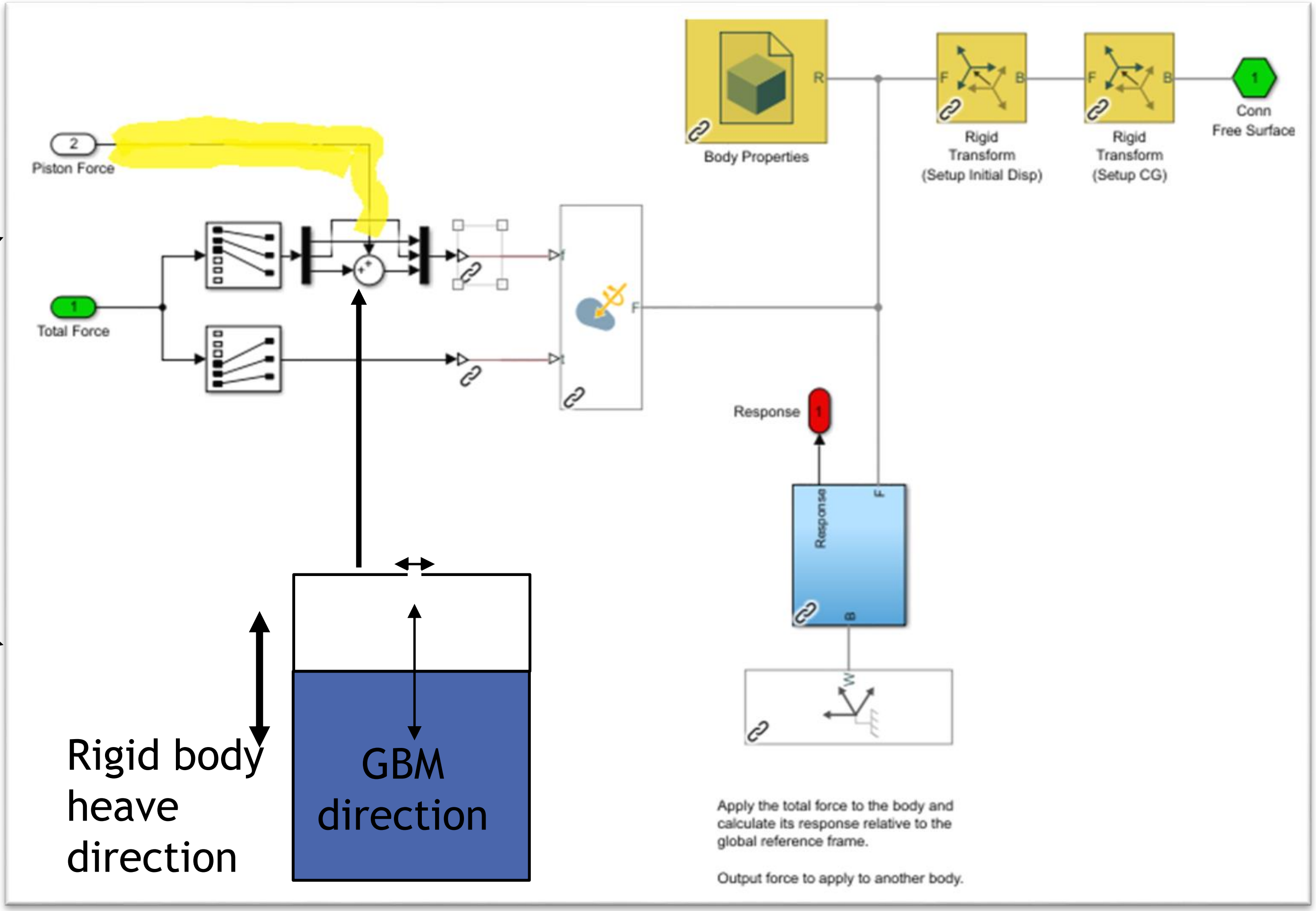
```
function [F_ext, dP, q, Pow]   = dPOrifice(A1,A2,Vz,C,rhoAir)

% inputs
% A1: Water Cyl area (m^2)
% A2: orifice area (m^2)
% C : orifice flow coeff. (empirical, use for fitting,
%    or solve iteratively @ each time step. Approx for fully dev. flow = 0.62)
% thresh: the threshold above which compressibility flagged (fraction of Mach number)
%   air temp assumed constant 293 K --> C = 343.2 m/s

% outputs
% dP: pressure drop across the orifice (kPa)
% q : flow rate through the orifice (m^3/s)
% Pow : instantaneous power dissipated through the orifice

q = A1 * Vz; % Continuity
V2 = q/A2; % Velocity at Orifice
dP = 0.001 * 0.5 * rhoAir * (q/ (C * A2)) * abs(q/ (C * A2)); % Pressure drop (kPa)
Pow =abs(q * dP); % Power through orifice

% F_fluid will always resist fluid motion, conserves instantaneous momentum
F_ext = -A1 * dP * 1000; % in Newtons

end
```



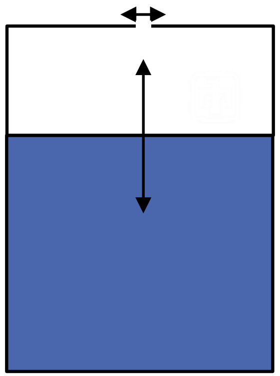
WEC-Sim modeling- Example

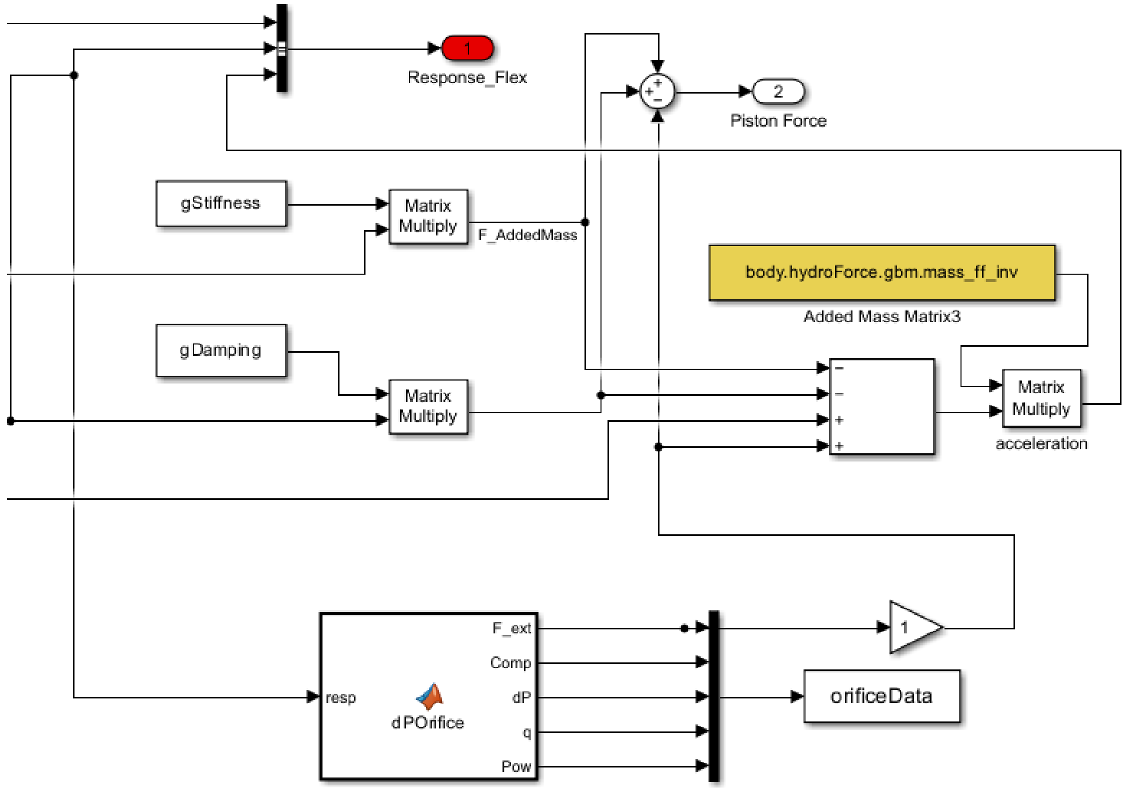
In this case, the GBM mode moves along an axis coincident with the rigid body heave direction AND the orifice is aligned with this direction: coupling forces are added to this direction.

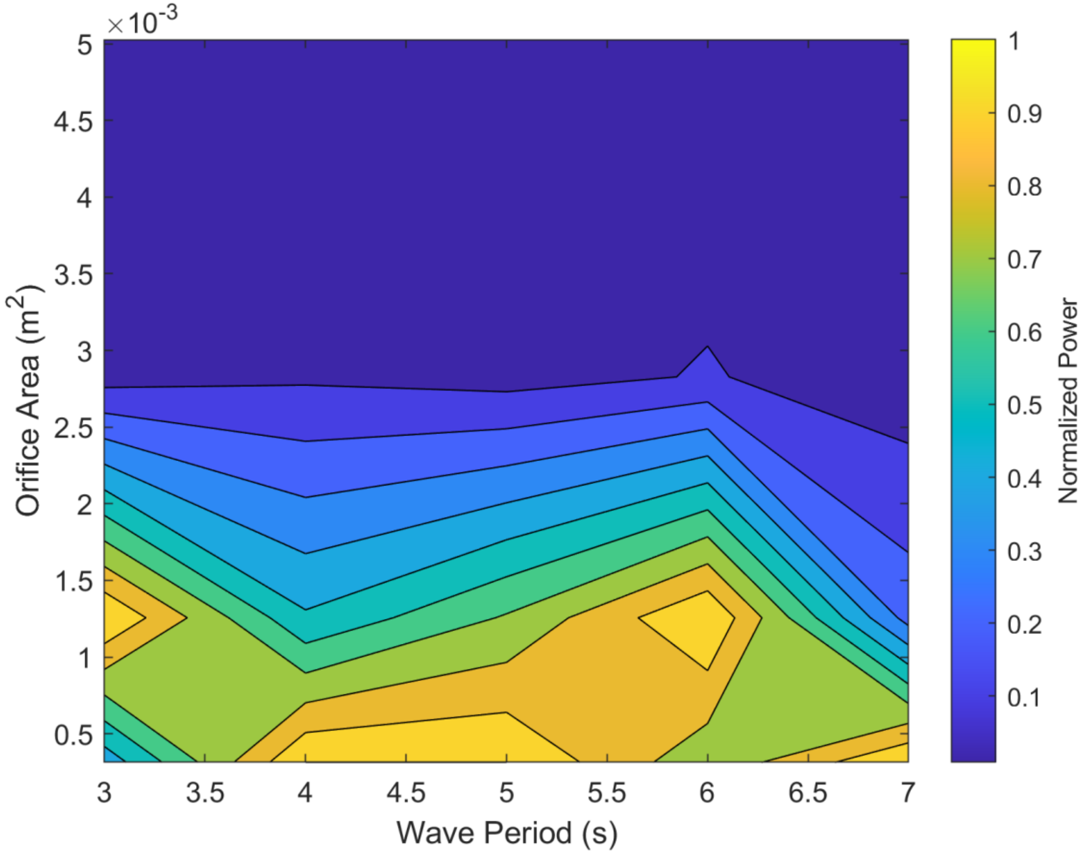




WEC-Sim modeling- Example

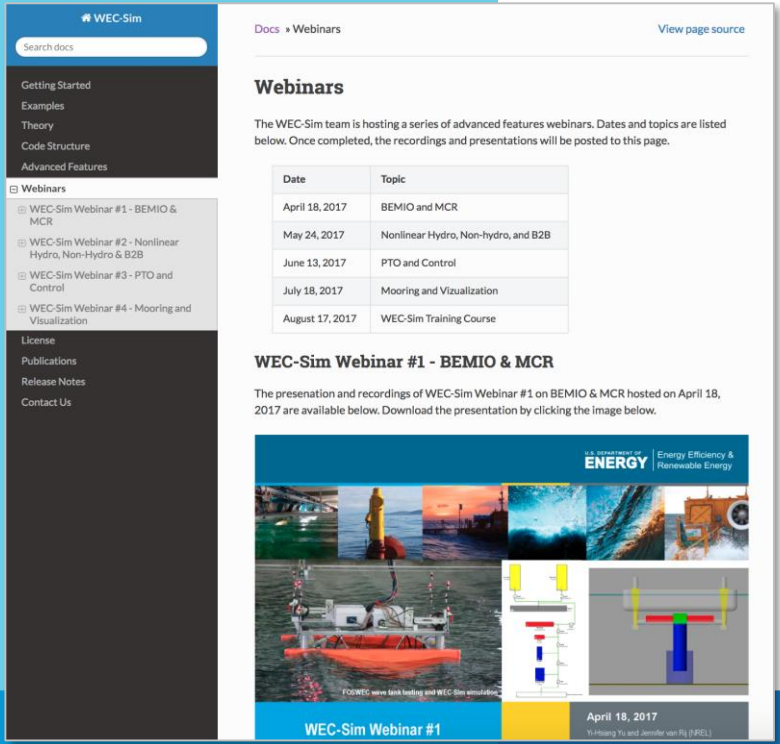






Thank you!

Additional materials and recordings are available online:
http://wec-sim.github.io/WEC-Sim/webinars.html



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